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Channel Estimation for MIMO – OFDM System

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Abstract:

The last few decades, there has been a incredible growth in the wireless communication technology. In this innovative information period, high data rate and strong reliability features are becoming the dominant factor for a successful exploitation of viable networks. MIMO-OFDM (Multiple Input Multiple Output – Orthogonal Frequency Division Multiplexing), is a new wireless broadband technology has gained great popularity for its capability of high rate transmission and its toughness against multipath fading and other channel impairments. In MIMO, multiple antennas are employed both at the transmitter and the receiver. Various signals are transmitted from different antennas at the transmitter using the same frequency and separated in space. In this paper, we analyze and implement channel estimation techniques such as Least Squares (LS) algorithm for MIMO-OFDM System. The MSE (Mean Square Error) performance characteristics of channel are investigated for BPSK, M-ary QAM modulation schemes over the AWGN and Rayleigh fading channel.

Keywords **—Channel Estimation, Multiple – Input Multiple Output (MIMO), Least Square Estimation Algorithm, Bit Error Rate.**

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I. INTRODUCTION

With the advancement in the technology, wireless communication has generated its new innovative approach for the different applications in various fields. The interest for higher information rates and rise in the range of wireless devices put an expanding interest on data transmission. It is taken as a basic technique in various systems with high data rate, for example IEEE standards such as 802.16.which results in large throughput and high efficiency of framework. Also there is no need of any expansion in bandwidth or transmission power. Due to this combinational approach, there may be great revolution in the field of communication.Basically, these techniques transmit different data streams on different transmit antennas simultaneously. By designing a suitable processing planning to handle these parallel streams of data, the data rate and/or the Signal-to-Noise Ratio (SNR) performance can be increased. Multiple Input Multiple Output (MIMO) systems are frequently combined with a spectrally efficient transmission technique called Orthogonal Frequency Division Multiplexing (OFDM) to avoid Inter Symbol Interference (ISI).

A. Multiple input and Multiple output (MIMO)

MIMO wireless antenna systems have been renowned as a key technology for future wireless communications. The performance of MIMO system can be enhanced by using multiple antennas at transmitting and receiving side to provide spatial diversity. The MIMO channel is represented with an antenna array with nt elements at the transmitter and an antenna array with nr elements at the receiver is considered.

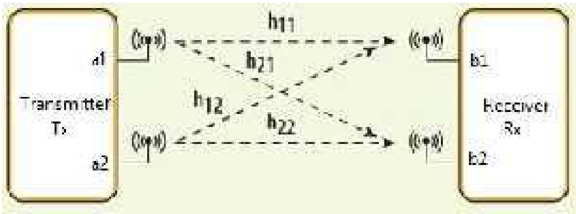
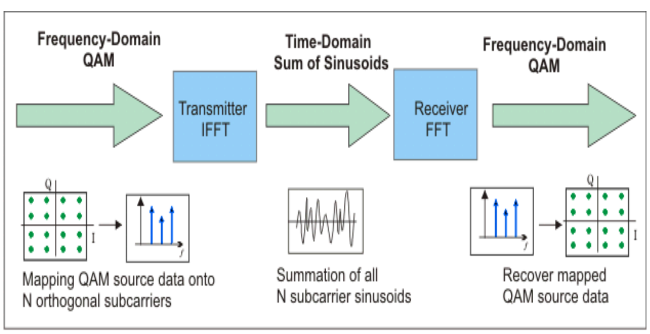


Fig.1 MIMO Block diagram

II. IMPLEMENTATION OF OFDM

OFDM systems mitigate this problem by utilizing a comparatively long symbol period. In addition, they do this without sacrificing throughput by utilizing multiple sub-carriers per channel. Below, we illustrate the time domain of OFDM symbols. Note that in an OFDM system, the symbol rate can be reduced while still achieving similar or even higher throughput.Note that OFDM channels are not the same as band constrained FDM channels how they apply a heartbeat forming channel. With FDM frameworks, a sink-formed heartbeat is applied in the time space to shape every individual image and forestall ISI. In request to utilize various sub-bearers to transmit an individual channel, an OFDM interchanges framework must play out a few stages.



Simplified OFDM System Block Diagram
Fig.2OFDM Process

B. Modulation with the inverse FFT

The modulation of data into a complex waveform occurs at the Inverse Fast Fourier Transform (IFFT) stage of the transmitter. Here, the modulation scheme can be chosen completely independently of the specific channel being used and can be chosen based on the channel requirements.In fact, it is possible for each individual sub-carrier to use a different modulation scheme. The role of the IFFT is to modulate each sub-channel onto the appropriate carrier.

III. MIMO SIGNAL MODEL

Consider a MIMO system equipped with $N_t$transmit antennas and $N_r$receive antennas. The block diagram of a typical MIMO 2×2 is shown in Figure. 1.

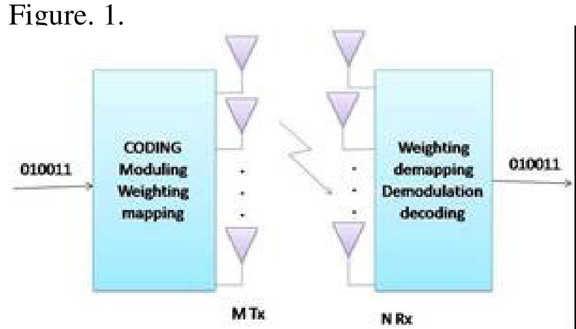


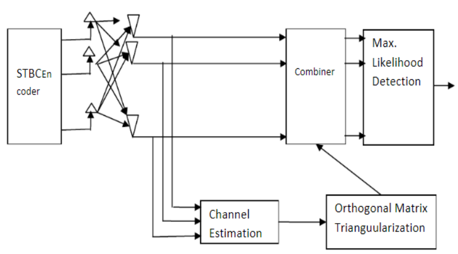
Fig.3General Architecture of MIMO

It is assumed that the channel coherence bandwidth is larger than the transmitted signal bandwidth so that the channel can be considered as narrowband or flat fading [10]. Furthermore, the channel is assumed to be stationary during the communication process of a block. Hence, by assuming the block Rayleigh fading model for flat MIMO channels, the channel response is fixed within one block and changes from one block to another one randomly. The idea behind MIMO is that the signal on the transmit (TX) antennas at one end and (RX) antennas at the other end are “combined” in such a way they receive that the quality or the data rate (bits/sec) of the communication for each MIMO user will be improved.In a single user MIMO model with N transmit and M receive antennas, the MIMO system equation is given by

$$\begin{bmatrix} r_1 \\ r_2 \\ \cdot \\ \cdot \\ \cdot \\ r_m \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} & \dots & h_{1n} \\ h_{21} & h_{22} & \dots & h_{2n} \\ \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots \\ h_{m1} & h_{m2} & \dots & h_{mn} \end{bmatrix} \begin{bmatrix} s_1 \\ s_2 \\ \cdot \\ \cdot \\ \cdot \\ s_n \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \\ \cdot \\ \cdot \\ \cdot \\ n_n \end{bmatrix}$$

Or in Matrix form: $r = Hs + n$

Where H is the channel matrix of size M x N, r is the M x 1 received signal vector, s is the N x 1 transmitted signal vector, and n is an M x 1 additive Guassian noise vector with zero mean and variance $\sigma 2$.



IV. PERFECT CHANNEL ESTIMATION

Perfect estimator is the simplest algorithm to estimate the channel matrix. By setting the noise equal to zero in (1), the perfect approach estimates the channel matrix as$H_{Perfect}$ = YS^{-1} (1)

In this way the channel matrix is simply will be obtained by inverse matrix of S/Y.

C. Least Square Algorithm

In this case we estimate the free noise MIMO channel perfectly. Perfect estimation will be used as a lower bound. Consider a Rayleigh flat-fading MIMO channel characterized by H, S as the training sequence, Y as related received signal. N represents Additive White Gaussian Noise. If we assume that:LS estimator finds $\hat{H}$ that $S\hat{H} \approx Y$.[6],[7]LS Algorithm, minimizes the Euclidian distance of $S\hat{H} - Y$.

INPUT BITS	I - OUT	Q - OUT
00	-1	-1
01	-1	+1
10	+1	-1
11	+1	+1

Table 1. Show the Input and the Output of QPSK modulator

For this minimization we do following steps:

$$\left\| S\hat{H} - Y \right\|^2 = \left(S\hat{H} - Y \right)^H \left(S\hat{H} - Y \right)$$

$$= \left(S\hat{H} \right)^H \left(S\hat{H} \right) - Y^H S\hat{H} - \left(S\hat{H} \right)^H Y + Y^H . Y \quad (2)$$

After derivation in respect to $\hat{H}$ and to put the equation equal the zero:

$$2S^H . S^H - 2S^H . Y = 0 \rightarrow S^H S\hat{H} = S^H . Y \quad (3)$$

And so we will have:

$\hat{H} = \left(S^H . S \right)^{-1} . S^H . Y$, the LS channel estimation algorithm.

D. Mean Square Error of the Channel estimation

The correlation matrix of the error of the channel estimations given by

$$R_{ee} = \left\{ \left[h_n - \hat{h}_n \right] \left[h_n - \hat{h}_n \right]^H \right\} (4)$$

For the Minimum Mean Square Error channel estimation itfollows to

$$R_{ee} = \left[S^H R_{nn}^{-1} S + R_{nn}^{-1} \right] (5)$$

The Mean Square Error (MSE) of a MIMO channel

$$MSE_{MIMO} = E\left\{ \left[\hat{h}_n - h_n \right]^H \left[\hat{h}_n - h_n \right] \right\} = \sigma_n^{\ 2} . Nt . tr(R_{ee})$$

is the trace of the error correlation matrix R_{ee}. The trace of a matrix denoted by tr (.) is the sum of the diagonal elements. For additive white noise the Mean Square Error follows to

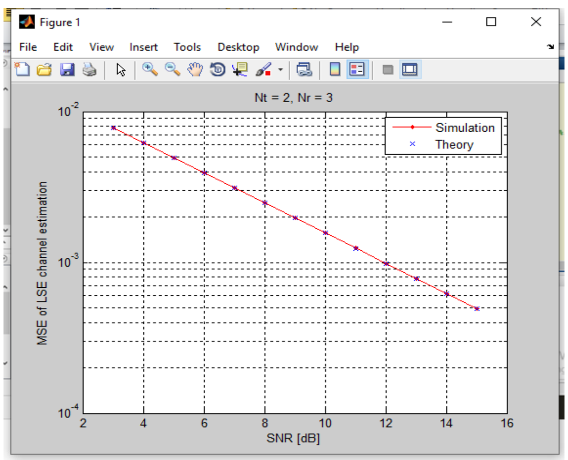
$$MSE_{MIMO} = \sigma_n^{\ 2}.Nt.tr\left(\left[S^H S + \frac{\sigma_n^{\ 2}}{\sigma_h^{\ 2}} I\right]^{-1}\right) \quad (6)$$

For the Least Square channel estimation the term

$\frac{\sigma_n^{\ 2}}{\sigma_h^{\ 2}}$ has to be set to zero.

V. EXPERIMENTS AND RESULTS

In this work the Simulation Results of the channel estimation are presented. The chosen network simulate or, c Matlab. The simulation results that are collected from the implementation of LS using the Matlab simulation are presented.



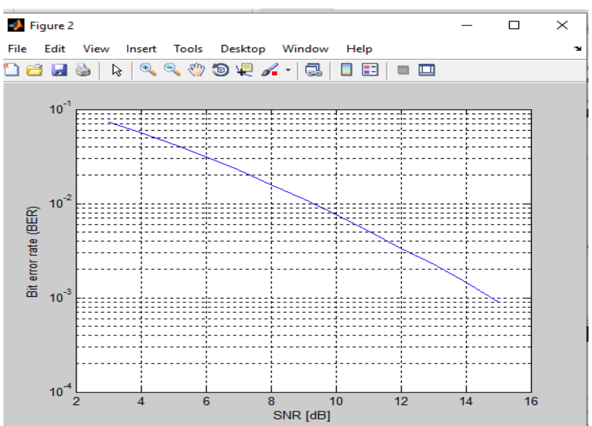


Figure shows BER comparison of MMSE and LS with respect perfect channel. LS estimator reduces the mean square error for a range of SNRs. Increasing the SNR is the reason for decreasing BER of all estimators but it is more effective for LS one.

VI. CONCLUSIONS

The bottleneck problem of complexity for channel estimation in MIMO-OFDM systems has been studied. In fact we have formulated the channel estimation problem in frequency domain. In this training based channel estimation schemes in flat fading MIMO systems are investigated. After introducing LS estimator, they simulated in a flat fading MIMO channel considering AWGN. Simulation results show that the algorithm of LS estimator is very simple, as this does not require correlation function calculation nor does it require matrix inversion. It is clear that LS estimator provides better performance in terms of mean square error (MSE) and bit error rate (BER). The LS estimation with different bit training values which shows BER decreases with large bit training values. From general modulation theory, performance is better for less order modulation technique as compared to high order modulation but in this data rate is larger. Same behavior is observed in MIMO system. Performance is same for all kinds of modulation at small value of SNR but as we increase the SNR value the performance gap goes on increasing.

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